



Adding CEA-LETI Non Volatile Memories for new design exploration

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NON VOLATILE MEMORY (NVM) MARKET TRENDS

- **Low/No energy consumption**

- Server cost due to power
- Battery replacement cost (IoT/VR/AR)

➔ **Higher integration of NVM within Logic**

- **Data-Centric computer architecture**

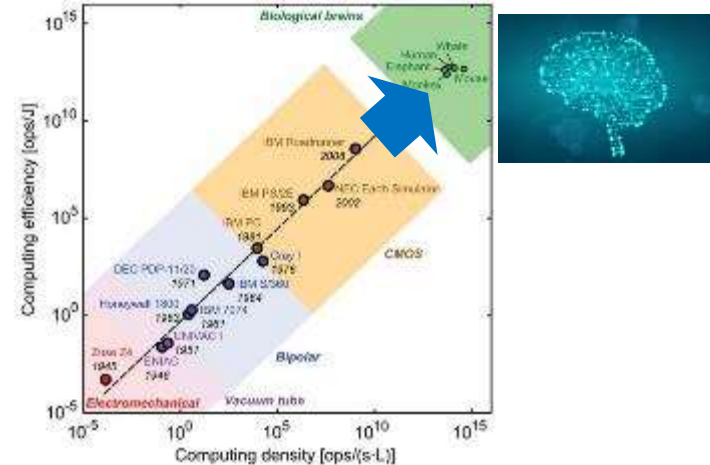
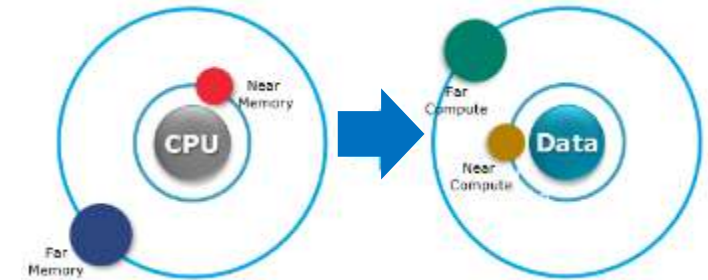
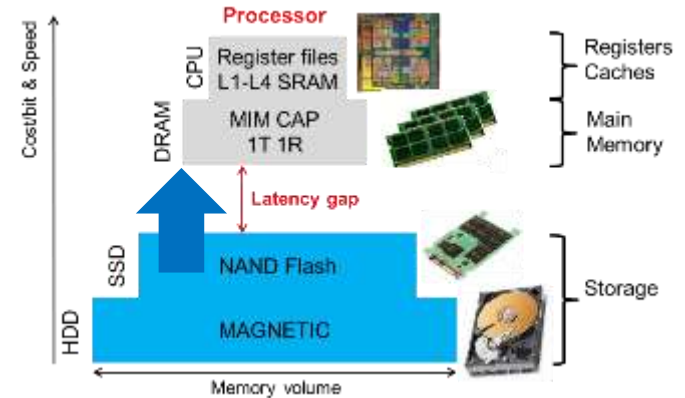
- Data movement constrained
- In-Memory processing / Distributed processing
- Machine learning/ Real time video analytics

➔ **Higher integration of Logic within NVM**

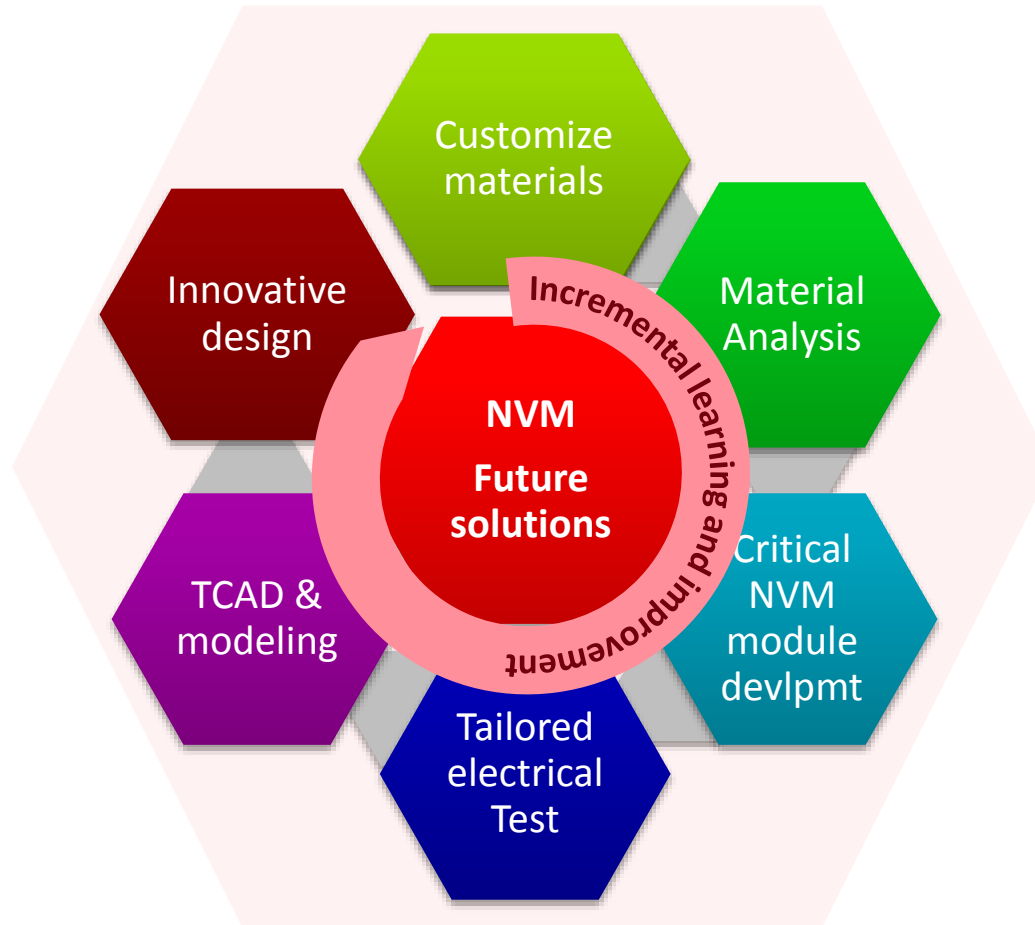
- **“Brain targeting”**

- Artificial spiking Neural Network / Neuromorphic
- Non-Von Neumann architecture

➔ **No Logic / NVM frontier**



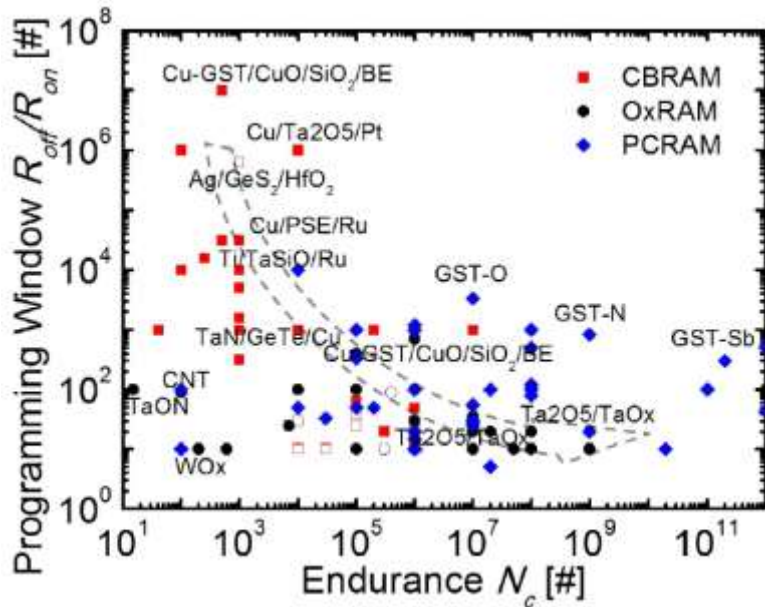
LETI MEMORY OFFER



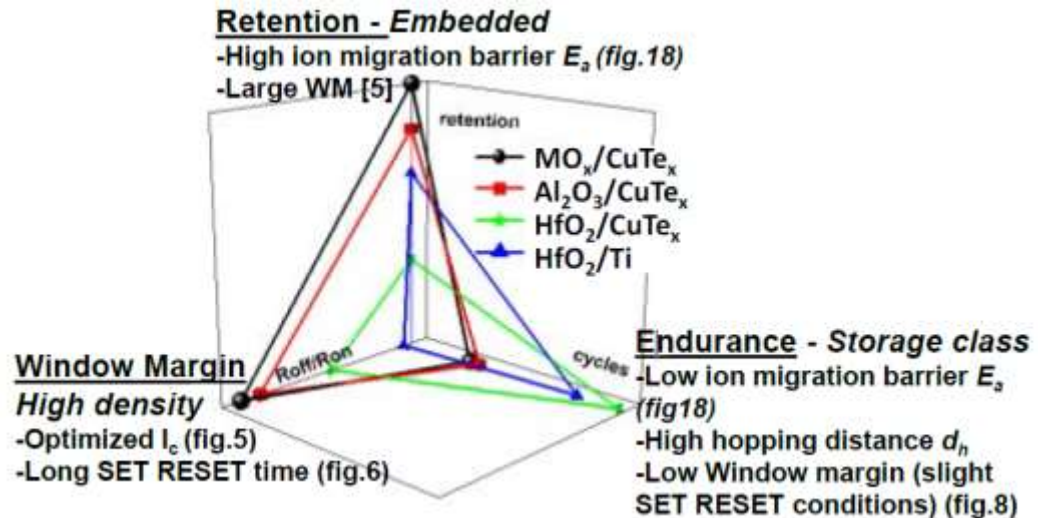
- **Dedicated to NVM next generation memory since >15 years**
- **A wide toolbox for customized research**
- **A benchmark between different BEOL technologies**
- **ReRAM technologies with state of the art performances**

LETI NVM PERFORMANCES ASSESSMENT

- General tradeoff between endurance, retention and window margin trade-off is observed
- Emerging memories are complementary with no clear winner from technological view point

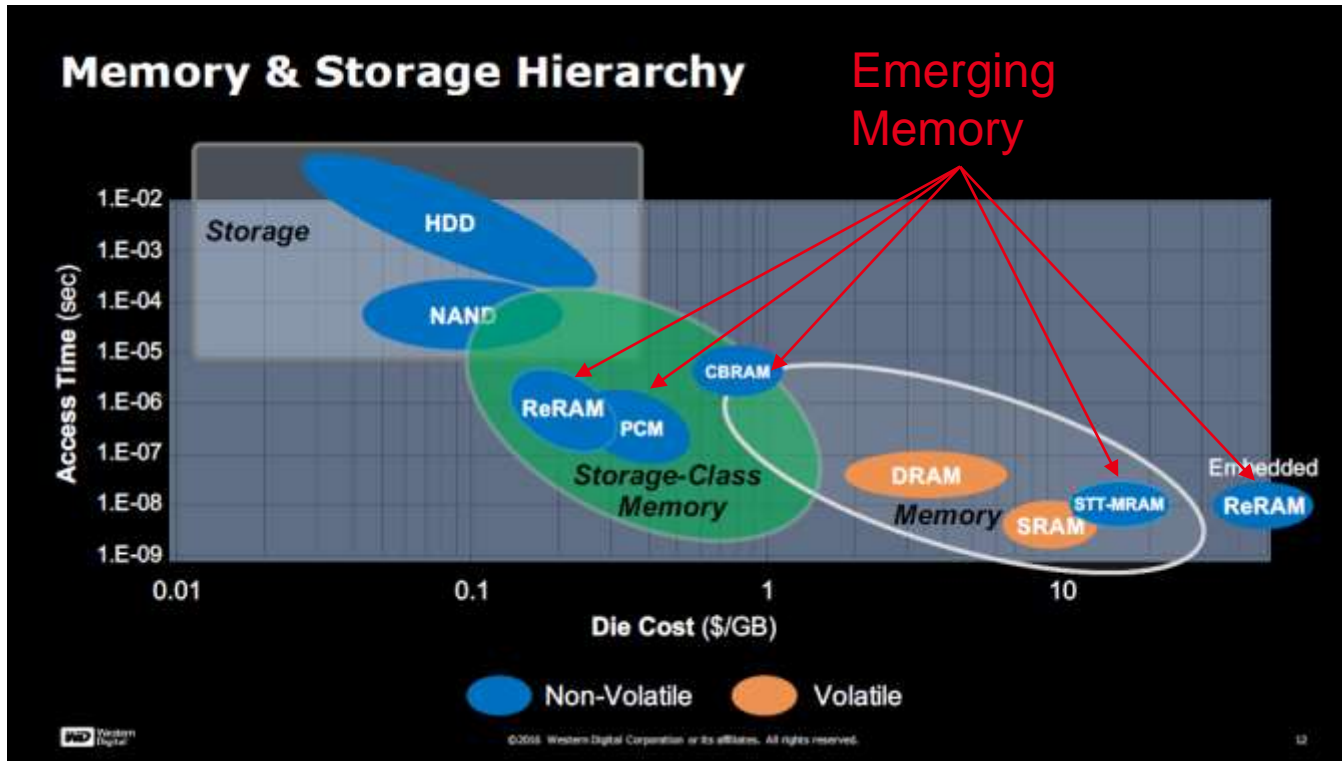


[L. Perniola, IMW 2016]



[C. Nail, IEDM 2016]

MEMORY MARKET DIRECTION



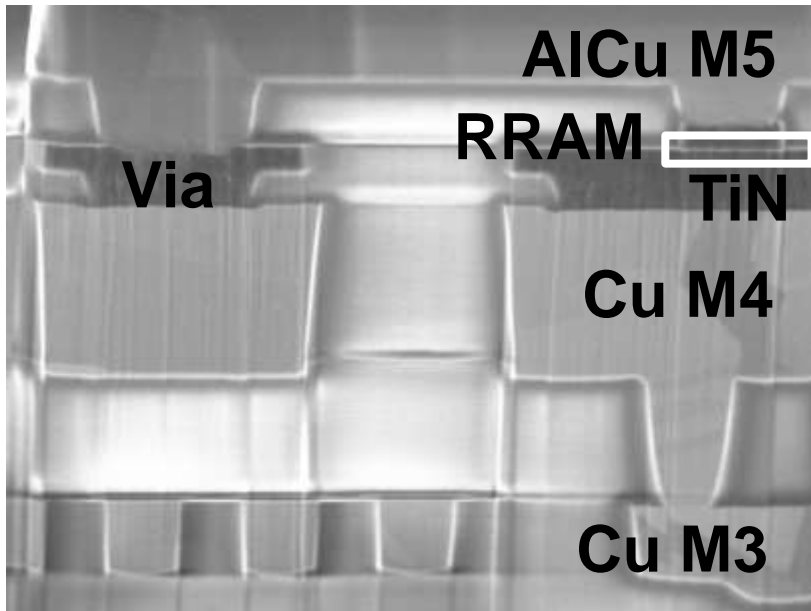
[Siva Sivaram
EVP of Memory
Technology,
Western Digital
Corporation

Flash memory
summit 2016]

- All emerging memories are **going to market**
- All emerging memories looks **complementary, no clear winner**

- ReRAM in Non Volatile Memory market
- **ReRAM technology at Leti**
- ReRAM electrical performances
- Why offer ReRAM ?

ReRAM Technology Integrated at Leti



[A. Grossi, IEDM 2016]

CMOS 130nm + 4 Cu Metal

TiN Bottom Electrode

CMP touch

Memory stack deposition
(HfO₂ 10nm/Ti 10nm/TiN)

Ø300nm Mesa Patterning

Encapsulation and CMP

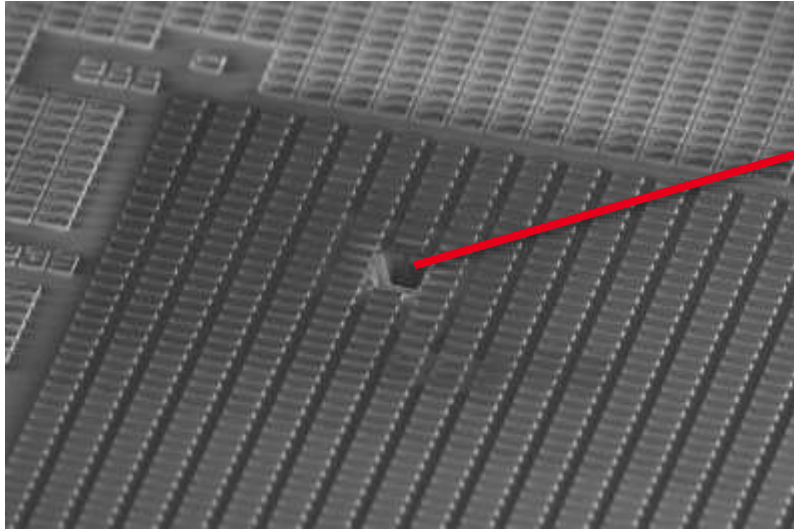
Via

M5

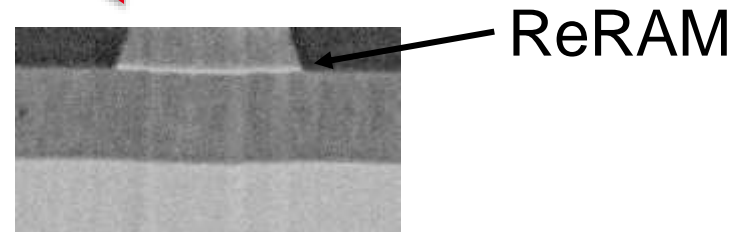
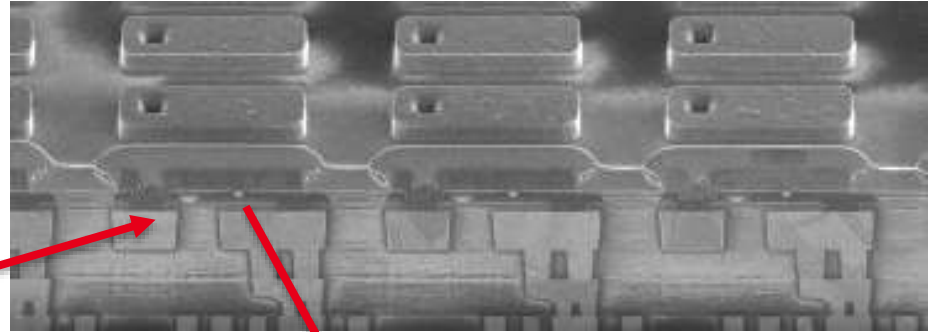


- OxRAM integrated on 130nm ST HCMOS9A
 - MIM stack: TiN / HfO₂ / Ti / TiN
- State of the art ReRAM technology

ReRAM Technology Integrated at Leti

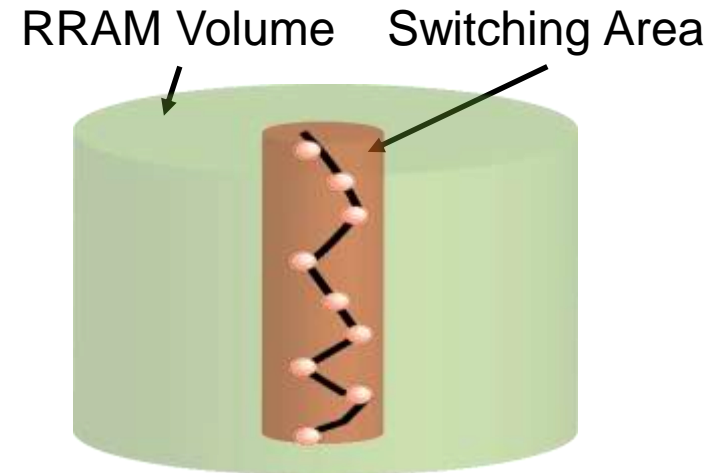


Kb NVM Array



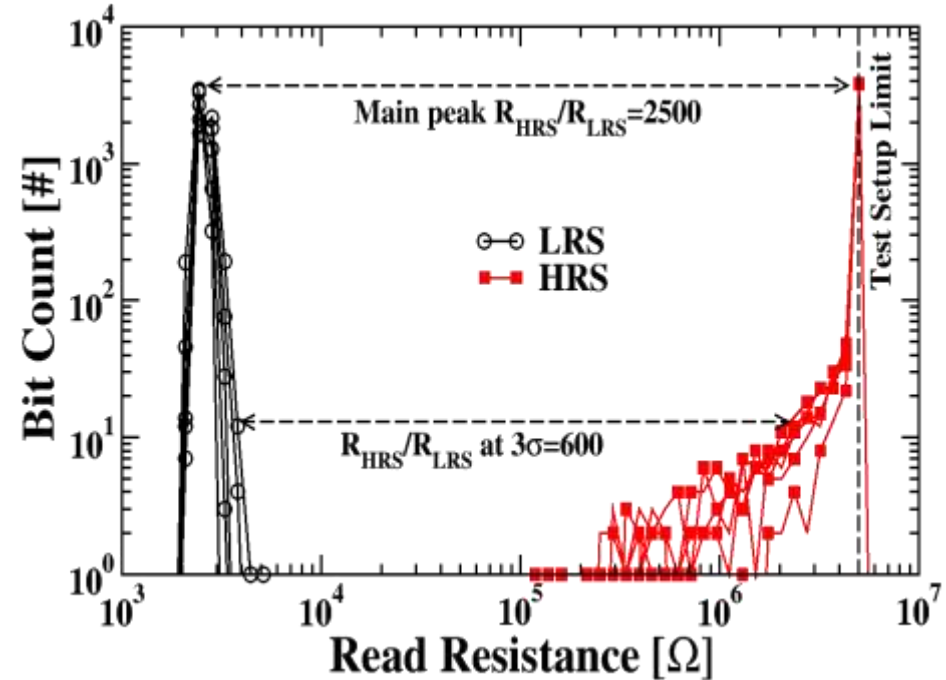
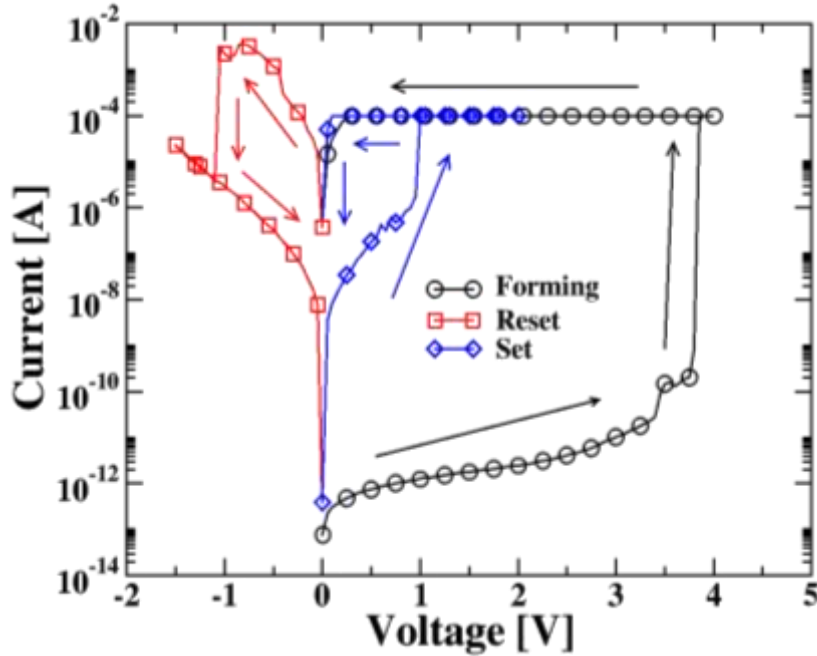
- Technology integrated and electrical performances assessed on Kb memory array

- A maturity high enough for design
- A disruptive technology
 - Resistive memory
 - Low voltage operation
 - Large reading window
 - Multi-level capability
 - Good endurance and retention
- ➔ **Representative of any NVM filamentary technology**



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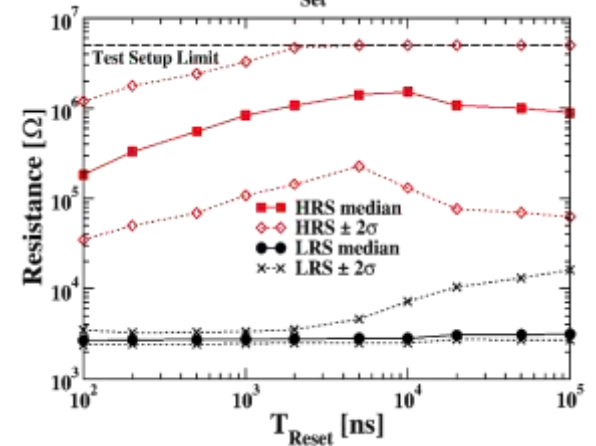
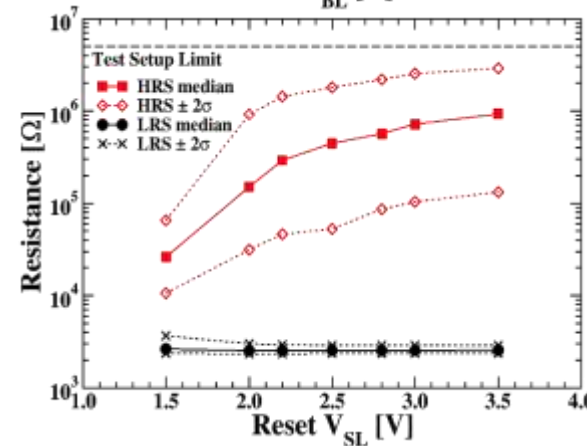
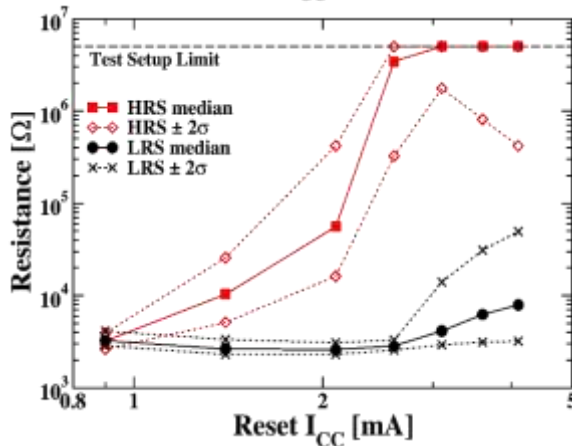
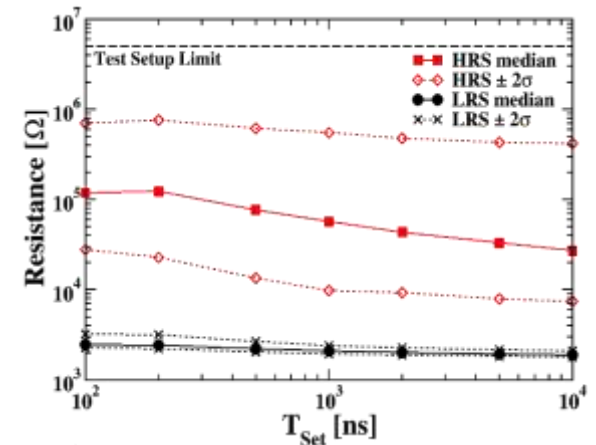
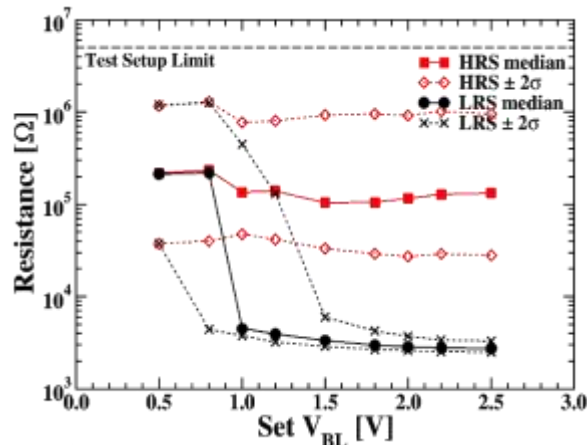
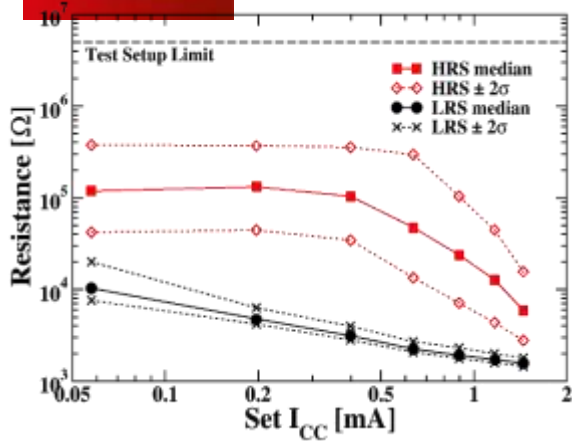
BASIC OPERATION FEATURE



[A. Grossi, IEDM 2016]

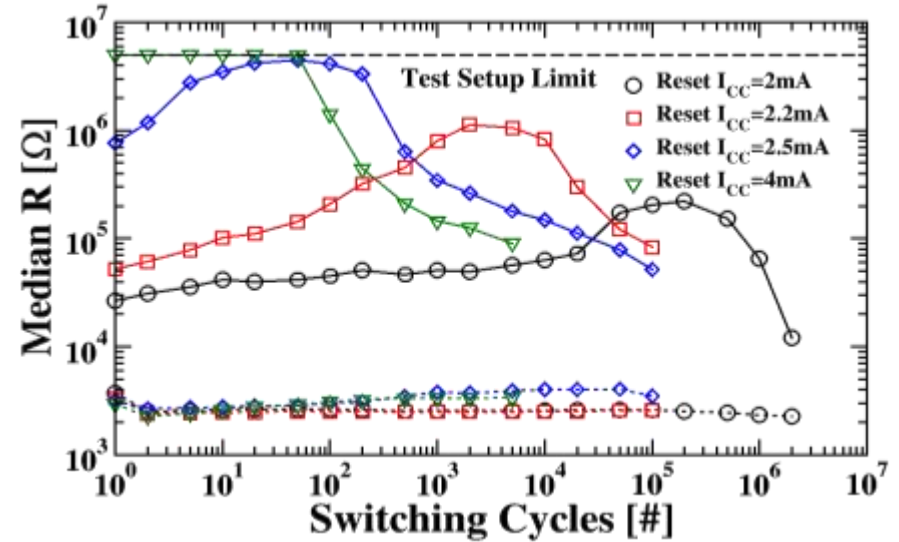
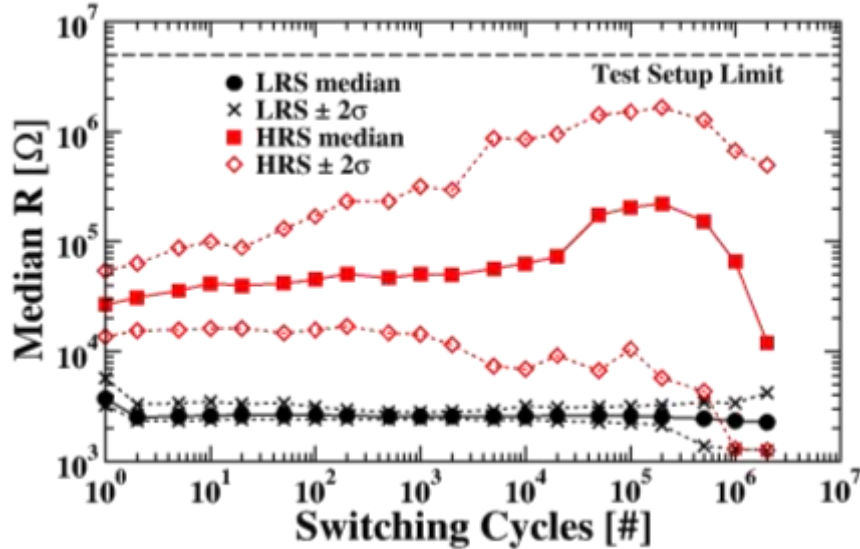
- Typical Forming, Set and Reset I-V curves
- On /Off distributions measured on 4kbits array

PROGRAMMING CONDITION



[A. Grossi, IEDM 2016]

- A complete set of Si-proven electrical parameters over a large range of operating conditions



[A. Grossi, IEDM 2016]

- Cycling behavior analyzed depending of the operating condition

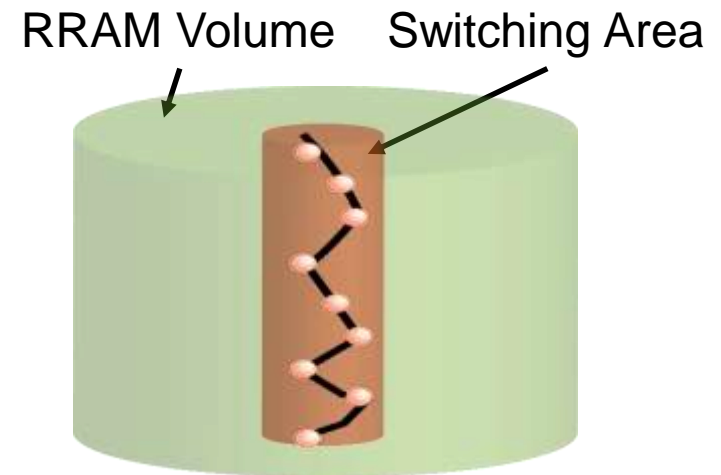
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- **A disruptive technology**

- Resistive memory
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- Good endurance and retention

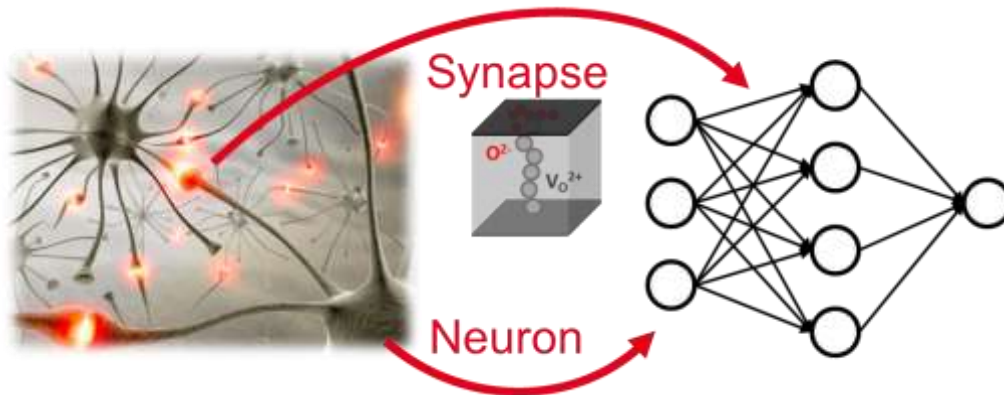
→ **Representative of any NVM
filamentary technology**

→ **A good memory but intrinsic physical
properties enables new computing
paradigm**

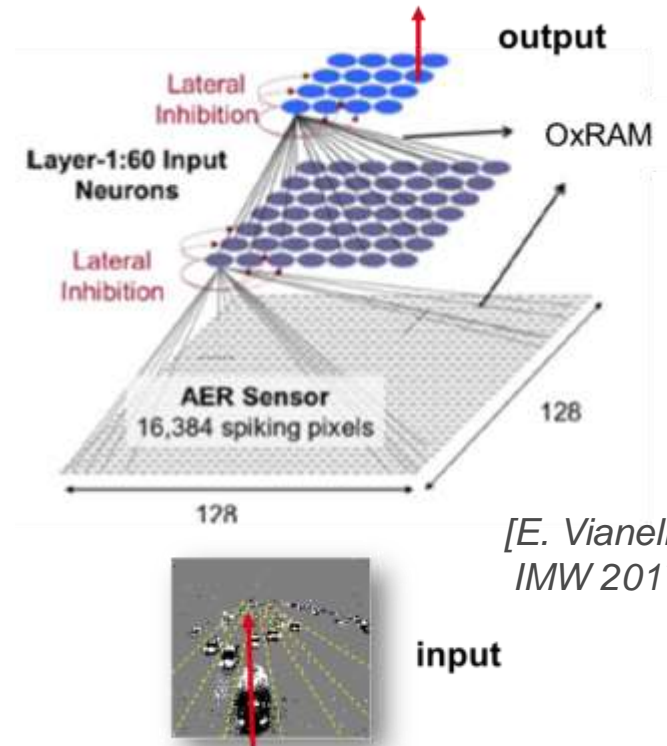


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- **Why offer ReRAM ?**

WHAT WE USE THIS TECHNOLOGY FOR AT CEA



[T. Werner, IEDM 2017]



[E. Vianello, IMW 2017]

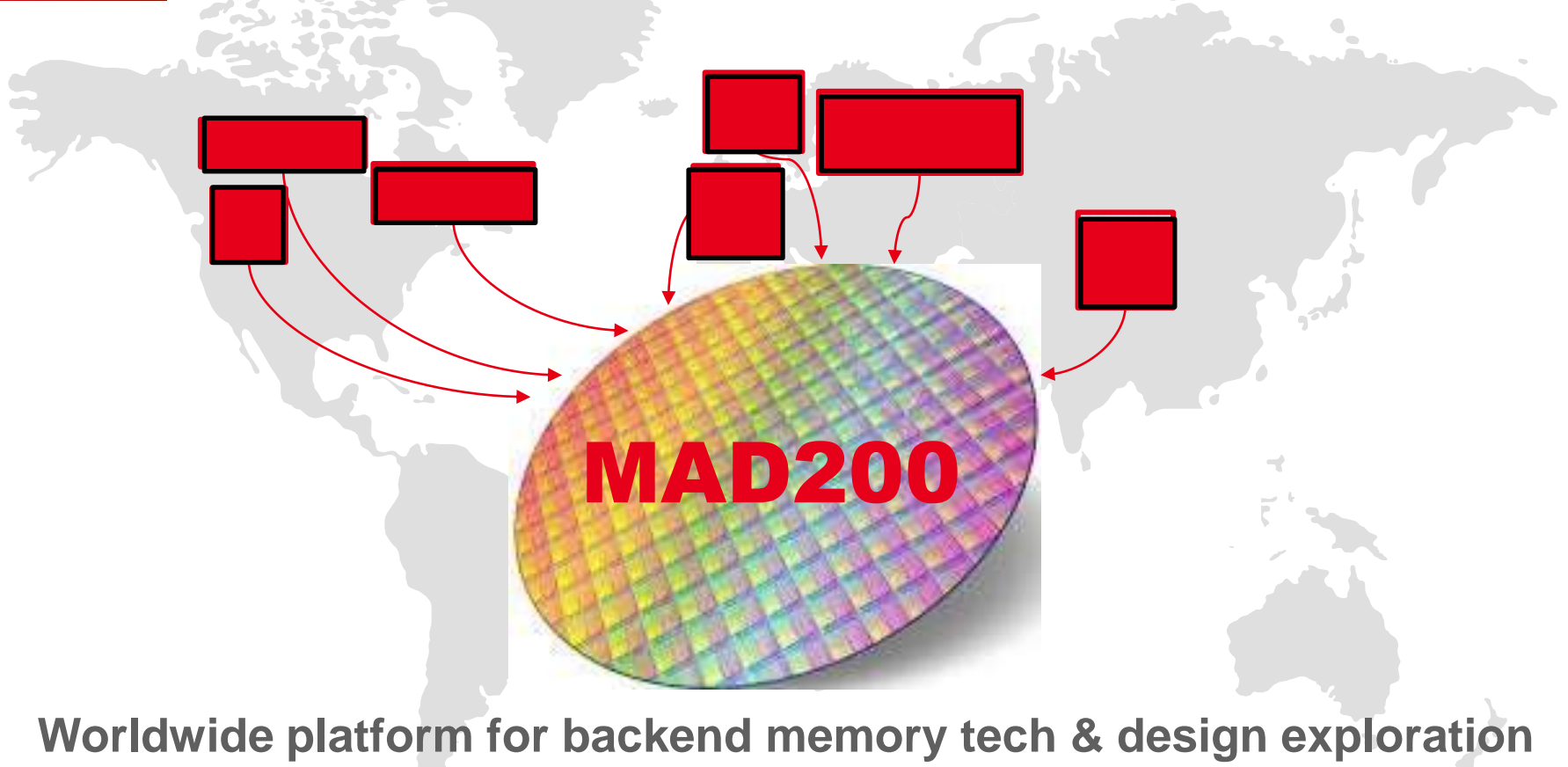
➤ OxRAM to implement HW synapses:

- online learning
- power consumption

➤ OxRAM for Deep-Learning accelerator

- high density
- power consumption

Continue collaboration with Designers for enabling NVM ecosystem



- Worldwide platform for backend memory tech & design exploration
- **Disruptive computing paradigms** → neuromimetic, machine learning...
- Work started internally on 300mm wafers

CONCLUSION

- **Multiple year project to add ReRAM state of the art technology on top of industrial platform**
- **First generation – CEA-Leti internal usage**
 - Started in 2015
 - Only Internal Leti design
- **Second generation – CEA-Leti / CMP collaboration**
 - Wafer out Today, under electrical test before transfer to CMP
 - Include external design of selected university partner
- **Third generation – Public opening - CEA-Leti / CMP / ST**
 - Plan for public opening Q4 2018
- **Goal : Enable research on new computing paradigm and algorithm development by opening new ReRAM technology offer**

Thank You!

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